NITROGEN STRENGTHENED FE-NI-CR ALLOY

BACKGROUND OF THE INVENTION

This invention relates generally to metal alloys containing substantial amounts of iron, nickel and chromium and more particularly to a carefully balanced composition suitable for use in aggressive environments at high temperatures.

DESCRIPTION OF THE PRIOR ART

Many people have attempted to develop alloys exhibiting high mechanical strength, low creep rates and good resistance to corrosion at various temperatures. In U.S. Pat. No. 3,627,516 Bellot and Hugo report that it was well known to make alloys having mechanical strength and corrosion resistance by including in the alloy about 30% to 35% nickel, 23% to 27% chromium and relatively low carbon, manganese, silicon, phosporus and sulfur. Mechanical properties of this type of alloy were improved by adding tungsten and molybdenum. Bellot and Hugo further improved this alloy by adding niobium in a range of from 0.20% to 3.0% by weight. Two years later in U.S. Pat. No. 3,758,294 they taught that high mechanical strength, low creep rate and good corrosion resistance could be obtained in the same type of alloy by including 1.0% to 8.0% niobium, 0.3% to 4.5% tungsten and 0.02% to 0.25% nitrogen by weight. Both patents teach a carbon content of the alloy in the range 0.05% to 0.85%.

Bellot and Hugo appear to have no concern about the hot workability and fabricability of their alloys. It is well known that carbon contents in excess of 0.20% greatly impair hot workability and fabricability. Many of the alloys disclosed by Bellot and Hugo have more than 0.20% carbon. The claims of both their patents require about 0.40% carbon. Because of these high carbon levels such alloys are difficult to hot work, fabricate or repair.

In U.S. Pat. No. 3,627,516 Bellot and Hugo attempt to avoid the use of expensive alloying elements such as tungsten and molybdenum to improve mechanical properties by adding 0.20% to 3.0% niobium. But in U.S. Pat. No. 3,758,294 they later find that tungsten is required to achieve high weldability and easy resistance to carburization. Thus, the teaching of Bellot and Hugo is that tungsten although expensvive is necessary to achieve high weldability in a corrosion resistant alloy.

Carbon and tungsten as well as other solid solution strengtheners such as molybdenum are used in alloys of the Ni-Cr-Fe family having generally about 15 to 45% nickel and 15 to 30% chromium to provide strength at high temperatures. The use of substantial amounts of carbon and solid solution strengtheners adversely affect thermal stability, reduce resistance to thermal cycling and usually raise the cost of the product excessively. Precipitation hardening is normally either limited to relatively low temperature strength improvements or has associated thermal stability and fabricability problems.

In addition to these strength considerations, prior art alloys of this family have only average corrosion resistance to aggressive high temperature environments such as those containing hydrocarbons, CO, CO_2 and sulfur compounds.

SUMMARY OF THE INVENTION

The present invention if a Fe-Ni-Cr alloy having improved mechanical properties and improved hot workability through the addition of a carefully controlled amount of nitrogen and the provision of nitrogen, columbium and carbon within a defined relationship. Preferably, columbium is added to comprise up to 1% of the alloy in order to produce complex carbonitride compound particles which form while the alloy is in service, and promote strengthening. Columbium also increases nitrogen solubility in the alloy, which allows for a higher level of nitrogen to be included in the alloy to yield higher strength. The presence of stronger nitride formers, such as aluminum and zirconium is limited to avoid excessive initial coarse nitride formation during alloy manufacture and consequent loss of strength. Chromium is present at levels over 12% to provide for both adequate oxidation resistance and adequate nitrogen solubility. In the presence of columbium, vanadium or tantalum in the alloy, a very small amount of titanium will have beneficial strengthening effects (not over 0.20% Ti). Silicon may be added up to 3.0% to optimize oxidation resistance, however, strength drops off markedly over about 1% Si. So two classes of alloy are possible: up to 1% Si has excellent strength and 1%–3% Si has lower strength but better oxidation resistance.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present alloy is a Fe-Ni-Cr alloy preferably having 25%–45% nickel and 12% to 32% chromium. More particularly the composition should fall within these ranges:

Ni-25% to 45%
Cr-12% to 32%
Cb-0.10 to 2.0% (min. 9 x carbon content)
Ti-Up to 0.20% max
Si-Up to 3% max
N-0.05 to 0.50%
C-0.02 to 0.20%
Mn-Up to 2.0% max
Al-Up to 1.0% max
Mo/W-Up to 5% max
B-Up to 0.02% max
Zr-Up to 0.2% max
Co-UP to 5% max
Y, La, Ce, REM-Up to 0.1% max

and the balance iron and typical impurities

The nitrogen in this alloy acts as a solid solution strengthener and also precipitates as nitrides in service as a further strengthening mechanism. The prior art involves alloys with generally less than enough nickel to provide a stable austenitic matrix when subjected to long term thermal aging in service at elevated temperature. Nitrogen acts to stabilize austenitic structure, but if nickel is less than 25%, once nitrides are precipitated during service exposure at greater than 1000° F., the matrix is depleted in nitrogen, and alloys are prone to embrittlement from sigma phase precipitation. To avoid this, our alloys contain greater than 25% Ni, and preferably greater than 30% Ni.

It is known that titanium in the presence of nitrogen in an iron-base alloy will form undesirable, coarse titanium nitride particles. These nitrides form during alloy manufacture and contribute little towards elevated temperature strength in service. The exclusion of titanium